

AMRL-TDR-64-41

AD 603 705

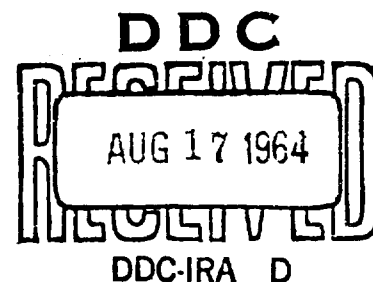
FINGER DEXTERITY OF THE PRESSURE-SUITED SUBJECT

DIETER E. WALK

16 p
Le - 1.00
28 0.50

TECHNICAL DOCUMENTARY REPORT No. AMRL-TDR-64-41

MAY 1964



BEHAVIORAL SCIENCES LABORATORY
AEROSPACE MEDICAL RESEARCH LABORATORIES
AEROSPACE MEDICAL DIVISION
AIR FORCE SYSTEMS COMMAND
WRIGHT-PATTERSON AIR FORCE BASE, OHIO

NOTICES

When US Government drawings, specifications, or other data are used for any purpose other than a definitely related government procurement operation, the government thereby incurs no responsibility nor any obligation whatsoever; and the fact that the government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data is not to be regarded by implication or otherwise, as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use, or sell any patented invention that may in any way be related thereto.

Qualified requesters may obtain copies from the Defense Documentation Center (DDC), Cameron Station, Alexandria, Virginia 22314. Orders will be expedited if placed through the librarian or other person designated to request documents from DDC (formerly ASTIA).

Do not return this copy. Retain or destroy.

Available from Office of Technical Services, Department of Commerce, Washington, D. C. 20230.

Change of Address

Organizations receiving reports via the 6570th Aerospace Medical Research Laboratories automatic mailing lists should submit the addressograph plate stamp on the report envelope or refer to the code number when corresponding about change of address.

FOREWORD

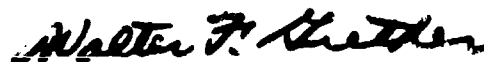
This study was conducted under Project No. 7184, "Human Performance in Advanced Systems," Task No. 718408, "Anthropology for Design." Special acknowledgements of appreciation are due to TSgt R.G. Ford, AlC B.R. Wirt and A2C R.R. Buckley of the Physiological Training Section, USAF Hospital, Wright-Patterson Air Force Base, for their invaluable help in controlling suit inflations and subject reactions while the subjects were tested in pressurized A/P-22S-2 pressure-ensembles. Thanks are also due to Mr. James Kramer and Mr. Reymond Middleton of Personal Equipment Branch, Directorate of Crew Subsystems Engineering, Research Technology Division, for their help in obtaining the pressure-suit ensembles used in these tests, and to the subjects for their willingness and cooperative attitudes in completing the tests. The author is grateful to Dr. Melvin J. Warrick, Assistant Chief of the Human Engineering Division, and to Mr. Charles E. Clauser, Assistant Chief of the Anthropology Branch, for critical comments and many helpful suggestions that materially improved the report; and to Mr. H.T.E. Hertzberg, Chief of the Anthropology Branch, for his support of the program, and for the critical review and sustained assistance in the writing of the report.

ABSTRACT

This study attempts to establish an objective baseline for evaluating the functional mobility of pressure gloves. The Purdue Pegboard Dexterity Test was employed to measure hand dexterity under three conditions: (1) subjects barehanded, but wearing an unpressurized A/P-22S-2 full-pressure suit ensemble; (2) subjects gloved (HAK-3/P-22S-2) and suited, but not pressurized; (3) subjects gloved, suited, and pressurized to 2.5 psi. The Purdue Pegboard Dexterity Test has been found to be a delicate indicator of hand dexterity in the test conditions. The test results show a marked reduction in dexterity even with the gloves and suit uninflated, and an additional loss when gloves and suit were inflated. The degree of loss of dexterity is believed to provide an objective measure whereby one operational aspect of pressure gloves may be evaluated.

PUBLICATION REVIEW

This technical documentary report is approved.



WALTER F. GRETHER
Technical Director
Behavioral Sciences Laboratory

FINGER DEXTERITY OF THE PRESSURE-SUITED SUBJECT

Dietar E. Walk

INTRODUCTION

The emphasis on handling materials and tools in space, both inside and outside the capsule, has been increasing almost day by day. Hence, it appeared appropriate to take a closer look at one of the factors which will play a major role in any manual task performed in space, ie, the loss of finger dexterity due to the wearing of pressure gloves. Hitherto, there has been no critically objective method of evaluating performance, dexterity, or mobility of gloves directly. The lack of emphasis on this type of evaluation may be explained by the expectation, in many cases, that only gross hand functions are to be accomplished in space, and by unwarranted assumptions that there will be little or no effect on performance caused by the wearing of gloves. For example, Hertzberg (ref 8) has shown that the grip strength of a gloved hand is considerably less than that of a bare hand; and Bradley (refs 2,3) has demonstrated the effect of gloves on hand tactility and performance under various conditions. I believe that the increasing sophistication of techniques and hardware items to be utilized in space forces a reevaluation of existing methods of assessing pressure-glove mobility and dexterity, so that future needs may be met.

The best possible condition of dexterity for any person is that of the bare hand. A glove has no "performance" in itself; therefore, any glove evaluation must be related finally to barehanded tests. If a baseline value of barehanded dexterity for each subject can be established by repeated tests, then the performance decrement due to gloves can be considered to be an impedance caused by new conditions.

The primary purpose of this study, then, is to assess the Purdue Pegboard method as an objective means of evaluating pressure glove mobility, dexterity, and tactility. An additional purpose has been to measure hand dexterity of subjects under three conditions: barehanded; gloved, uninflated; and gloved, inflated.

MATERIALS

In these experiments, the HAK-3/P-22S-2 full-pressure glove was selected because of its wide acceptance in the Air Force as a part of the operational A/P-22S-2 full-pressure ensemble.

The Purdue Pegboard manipulative dexterity test has been chosen from a variety of such tests (refs 5,9,11,12) because the tasks to be accomplished appear to be the most delicate of those surveyed. In other words, the Purdue Pegboard test is probably the most demanding of the tests, and hence constitutes one extreme limit of the tasks capable of being performed in space.* Furthermore, since this test has been performed on thousands of subjects, well-validated profiles of the population are available.

The A/P-22S-2 full-pressure suit ensemble was employed in these tests according to the manner proscribed by the Operation and Service Manual issued by the David Clarke Company. The sizes of these items needed for the 17 subjects are listed in table 1.

TABLE 1

SIZES OF HAK-3/P-22S-2 GLOVES AND A/P-22S-2 SUITS*

| Sizes | Gloves | | | | | | | | | | | |
|-----------------|--------|---|---|---|---|---|---|---|---|---|---|---|
| | A | B | C | D | E | F | G | H | I | J | K | L |
| No. of Subjects | | 2 | 3 | | 3 | | | 2 | 4 | | 3 | |

| Sizes | Suits | | | | | | | |
|-----------------|-------|----|----|----|----|----|-----|-----|
| | SR | SL | MR | ML | LR | LL | XLR | XLL |
| No. of Subjects | 1 | 4 | 2 | 4 | | 1 | 5 | |

*References 1 and 4

No ventilating garment was needed in these tests because the subjects were kept comfortably cooled by the air that was fed into the suits through their standard ventilating systems. All tests were conducted at ordinary room temperature.

*As this report was being prepared for publication, Pierce's paper (ref 10) appeared in March 1964. Although prepared completely independently, the two reports substantiate each other.

THE SAMPLE

Seventeen college men were chosen as a convenient sample to serve as subjects for this test. All were normal, healthy males. None had had experience in wearing pressure suits.

The subjects were measured for the following dimensions:

1. Stature
2. Weight
3. Hand Length
4. Hand Circumference at Metacarpale

They ranged in Stature from 160.5 cm (63.2 inches), the 1st percentile (ref 7), to 183.3 cm (72.2 inches), the 90th percentile; in Weight from 60.6 kg (133.5 lbs), the 5th percentile, to 100 kg (220 lbs), the 99th percentile; in Hand Length from 179 mm (7.0 inches), the 10th percentile, to 207 mm (9.4 inches), the 99th percentile; and in Hand Circumference from 191 mm (7.5 inches) to 230 mm (9.0 inches).^{*} Thus, in these dimensions, they appeared to be a reasonably representative sample of the Air Force population. The first two dimensions were necessary for the proper fitting of the pressure suits, and the last two for the pressure gloves.

TEST CONDITIONS AND METHODS

The three test conditions are as follows:

1. The barehanded subject wore an uninflated A/P-22S-2 pressure suit, with the visor up. See figure 1.
2. The subject wore the uninflated HAK-3/P-22S-2 gloves and the pressure suit with the visor up. See figure 2.
3. The subject wore the suit and gloves inflated to 2.5 psi with the visor down. See figure 3.

Each subject was dressed in the full-pressure ensemble, and individual suit adjustments were made to insure proper fit. During this period each subject was given an oral orientation describing the working principle of the suit, and the subject moved about so as to become familiar with body mobility within the suit. Following this familiarization period, the subject was seated at the test table, the instructions as prescribed by the pegboard test manual were given him, and trials were performed according to condition 1.

^{*}Hand Circumference at Metacarpale was not included in the 1950 Survey, hence no percentile designations are available for this dimension.



RIGHT HAND



LEFT HAND



BOTH HANDS

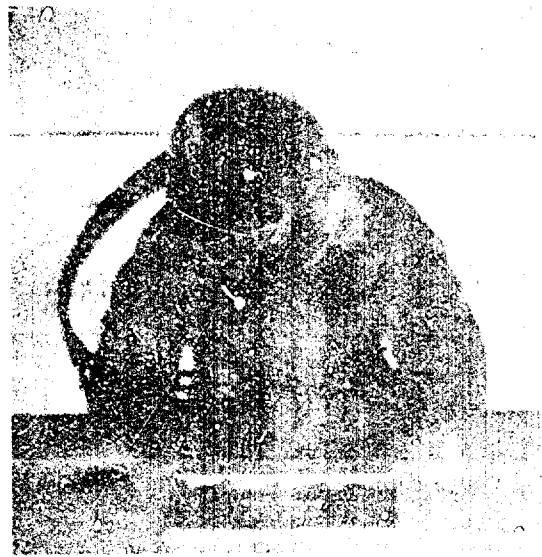


ASSEMBLY

Figure 1. Condition 1: Subject Suited, but Barehanded
(Visor Up, Unpressurized)



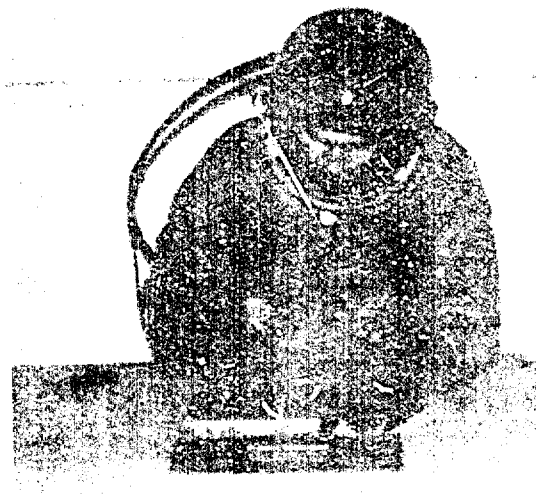
RIGHT HAND



LEFT HAND

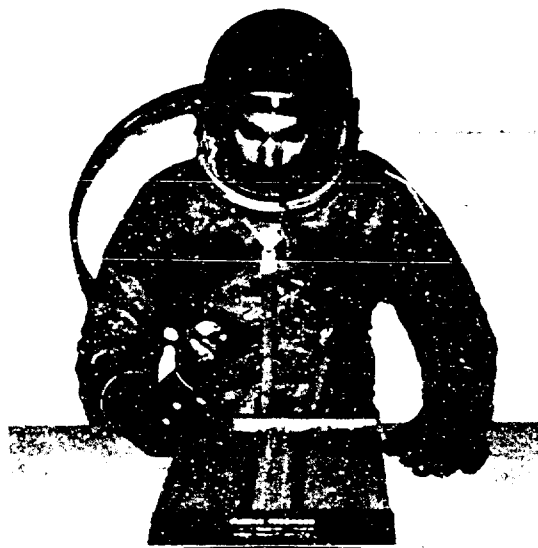


BOTH HANDS



ASSEMBLY

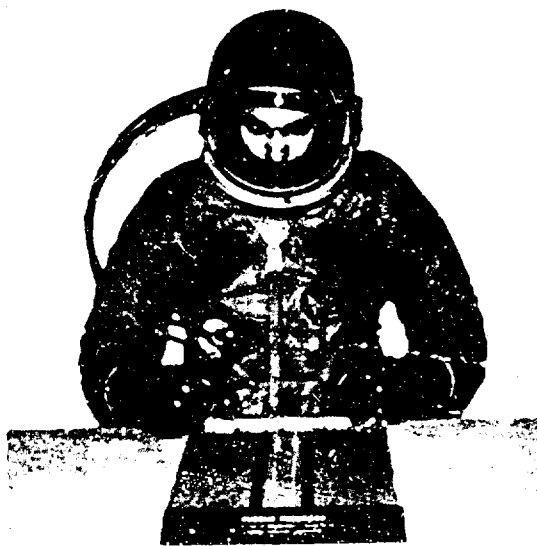
Figure 2. Condition 2: Subject Suited and Gloved
(Visor Up, Unpressurized)



RIGHT HAND



LEFT HAND



BOTH HANDS



ASSEMBLY

Figure 3. Condition 3: Subject Suited and Pressurized to 2.5 psi (Visor Down)

Next, pressure gloves were fitted to the subject and were secured to the suit to fulfill condition 2. For each test the monitor (a) pushed the glove fingers onto the subject's fingers to ensure that the subject's fingertips fitted snugly into the glove fingertips, and (b) tightened the adjustable strap buckles on the backs of the gloves to assure retention of maximum snugness. Wearing the complete pressure ensemble, but with the suit unpressurized and the visor up, the subject again performed the standard battery of tests.

For tests to meet condition 3, the subject's visor was closed and the suit was pressurized to 2.5 psi. No further adjustments were made to the pressure gloves during this test condition. Though the A/P-22S-2 full-pressure suit is operationally a 3.5 psi suit, the pressurized trials were conducted at 2.5 psi for two reasons: (a) the major portion of the ballooning or "growth" of the suit and its components has already occurred, and (b) additional pressure results in increased stiffening of the suit cloth, which inhibits movement of the shoulder and elbow and reduces arm mobility, thereby affecting performance. For these pressurized trials the test instructions were followed exactly, except that the pegboard was turned 180° so that mobility restrictions of the pressurized suit would not influence test results (see figures 1, 2, and 3). This 180° rotation brought the board cups close to the subject so that he needed to move only his wrist and fingers, not his entire arm, thereby eliminating a possible variable.

All subjects were tested in the same room, on the same furniture, and were given the same instructions by the same monitors. The only variables for each subject were the test conditions.

RESULTS AND DISCUSSION

Table 2 presents the detailed scores achieved by each of the 17 subjects in each task and condition. Inspection shows that the scores of the three repetitions of each task have low variabilities and that the trend to reduced dexterity is the same throughout.

This trend is more concisely shown by table 3, which summarizes the data of table 2.

By expressing the barehanded data as 100% of the combined subjects' original capability, we establish a constant base of comparison, despite the variability in individual performance. Thus converted, the data show the values in table 4.

Because of the direction and magnitude of the decrement in test scores of the gloved hand, and the further decrement of the pressurized hand, it appears reasonable to consider this test to be a fairly delicate measure of the manipulative capability of the pressure-gloved hand. Of course, every effort was made to provide perfect fit for each subject in the suit and in the gloves, and these were generally excellent. Nevertheless, the 2.5 psi pressurization magnified any slight mis-match between

TABLE 2
DEXTERITY TEST: RAW SCORES

| SUBJECT | CONDITIONS | TRIALS: | RIGHT HAND | | | LEFT HAND | | | BOTH HANDS | | | ASSEMBLY* | | |
|---------|---------------------|---------|------------|----|----|-----------|----|----|------------|----|----|-----------|----|----|
| | | | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 |
| 1 | Barehanded | | 15 | 14 | 16 | 11 | 14 | 14 | 11 | 11 | 11 | 33 | 40 | 44 |
| | Gloved, no pressure | | 6 | 9 | 9 | 8 | 9 | 10 | 5 | 4 | 7 | 16 | 15 | 18 |
| | Gloved, 2.5 psi | | 4 | 4 | 4 | 2 | 3 | 5 | 3 | 4 | 2 | 9 | 9 | 6 |
| 2 | Barehanded | | 14 | 15 | 14 | 15 | 16 | 17 | 13 | 13 | 12 | 40 | 39 | 42 |
| | Gloved, no pressure | | 10 | 10 | 10 | 9 | 10 | 13 | 8 | 7 | 6 | 12 | 15 | 20 |
| | Gloved, 2.5 psi | | 5 | 5 | 7 | 7 | 7 | 7 | 2 | 3 | 3 | 6 | 7 | 3 |
| 3 | Barehanded | | 14 | 15 | 15 | 14 | 16 | 15 | 14 | 13 | 16 | 44 | 46 | 48 |
| | Gloved, no pressure | | 7 | 8 | 10 | 5 | 8 | 8 | 5 | 5 | 4 | 12 | 12 | 15 |
| | Gloved, 2.5 psi | | 5 | 5 | 2 | 4 | 3 | 5 | 0 | 2 | 2 | 6 | 5 | 6 |
| 4 | Barehanded | | 19 | 15 | 18 | 17 | 17 | 16 | 13 | 13 | 15 | 48 | 45 | 47 |
| | Gloved, no pressure | | 11 | 8 | 10 | 10 | 10 | 8 | 8 | 7 | 7 | 17 | 17 | 19 |
| | Gloved, 2.5 psi | | 4 | 5 | 3 | 3 | 4 | 4 | 3 | 2 | 1 | 10 | 8 | 11 |
| 5 | Barehanded | | 15 | 16 | 15 | 18 | 17 | 19 | 12 | 14 | 14 | 37 | 28 | 36 |
| | Gloved, no pressure | | 12 | 13 | 11 | 12 | 13 | 12 | 9 | 11 | 11 | 18 | 20 | 15 |
| | Gloved, 2.5 psi | | 8 | 8 | 6 | 7 | 7 | 5 | 4 | 3 | 4 | 12 | 7 | 16 |
| 6 | Barehanded | | 17 | 16 | 19 | 17 | 16 | 15 | 13 | 13 | 13 | 38 | 44 | 47 |
| | Gloved, no pressure | | 8 | 7 | 11 | 8 | 9 | 10 | 7 | 5 | 7 | 15 | 17 | 14 |
| | Gloved, 2.5 psi | | 3 | 6 | 5 | 3 | 6 | 3 | 1 | 3 | 3 | 8 | 6 | 8 |
| 7 | Barehanded | | 16 | 16 | 18 | 14 | 17 | 14 | 14 | 14 | 15 | 34 | 34 | 44 |
| | Gloved, no pressure | | 13 | 13 | 13 | 10 | 12 | 13 | 10 | 9 | 9 | 16 | 18 | 22 |
| | Gloved, 2.5 psi | | 8 | 7 | 5 | 5 | 7 | 6 | 4 | 4 | 4 | 10 | 4 | 7 |
| 8 | Barehanded | | 17 | 18 | 19 | 15 | 17 | 18 | 14 | 14 | 13 | 36 | 43 | 43 |
| | Gloved, no pressure | | 12 | 14 | 15 | 13 | 12 | 13 | 8 | 7 | 10 | 21 | 20 | 22 |
| | Gloved, 2.5 psi | | 6 | 5 | 7 | 5 | 5 | 6 | 4 | 1 | 3 | 8 | 13 | 14 |
| 9 | Barehanded | | 18 | 20 | 20 | 16 | 17 | 19 | 13 | 15 | 16 | 46 | 48 | 51 |
| | Gloved, no pressure | | 15 | 15 | 16 | 14 | 13 | 14 | 10 | 10 | 9 | 27 | 27 | 26 |
| | Gloved, 2.5 psi | | 10 | 8 | 8 | 9 | 6 | 8 | 6 | 4 | 5 | 12 | 14 | 13 |
| 10 | Barehanded | | 15 | 16 | 16 | 14 | 16 | 17 | 11 | 14 | 11 | 38 | 33 | 40 |
| | Gloved, no pressure | | 12 | 13 | 13 | 14 | 13 | 12 | 7 | 8 | 9 | 17 | 18 | 18 |
| | Gloved, 2.5 psi | | 8 | 8 | 7 | 8 | 6 | 6 | 3 | 2 | 3 | 6 | 10 | 10 |
| 11 | Barehanded | | 15 | 16 | 17 | 15 | 15 | 16 | 13 | 12 | 13 | 31 | 41 | 45 |
| | Gloved, no pressure | | 12 | 13 | 12 | 12 | 11 | 12 | 8 | 8 | 8 | 17 | 24 | 27 |
| | Gloved, 2.5 psi | | 7 | 7 | 8 | 6 | 7 | 8 | 3 | 5 | 5 | 10 | 10 | 12 |
| 12 | Barehanded | | 15 | 17 | 19 | 16 | 18 | 17 | 14 | 15 | 16 | 40 | 43 | 46 |
| | Gloved, no pressure | | 12 | 12 | 13 | 11 | 12 | 13 | 8 | 9 | 8 | 16 | 17 | 22 |
| | Gloved, 2.5 psi | | 6 | 5 | 6 | 7 | 9 | 9 | 4 | 3 | 5 | 6 | 10 | 14 |
| 13 | Barehanded | | 16 | 15 | 17 | 17 | 19 | 18 | 14 | 16 | 14 | 31 | 40 | 42 |
| | Gloved, no pressure | | 4 | 8 | 7 | 9 | 7 | 7 | 3 | 4 | 4 | 12 | 14 | 11 |
| | Gloved, 2.5 psi | | 3 | 3 | 4 | 4 | 4 | 4 | 0 | 3 | 1 | 2 | 6 | 5 |
| 14 | Barehanded | | 16 | 15 | 18 | 16 | 16 | 16 | 15 | 14 | 16 | 46 | 51 | 56 |
| | Gloved, no pressure | | 8 | 10 | 11 | 7 | 10 | 8 | 7 | 6 | 8 | 22 | 21 | 23 |
| | Gloved, 2.5 psi | | 7 | 7 | 7 | 7 | 8 | 7 | 3 | 5 | 2 | 4 | 3 | 6 |
| 15 | Barehanded | | 17 | 17 | 18 | 15 | 17 | 17 | 14 | 14 | 15 | 45 | 49 | 52 |
| | Gloved, no pressure | | 10 | 11 | 12 | 8 | 8 | 12 | 7 | 7 | 4 | 22 | 21 | 19 |
| | Gloved, 2.5 psi | | 4 | 6 | 7 | 9 | 7 | 8 | 5 | 3 | 3 | 10 | 14 | 15 |
| 16 | Barehanded | | 16 | 14 | 17 | 16 | 18 | 18 | 12 | 14 | 14 | 45 | 45 | 56 |
| | Gloved, no pressure | | 10 | 9 | 10 | 11 | 9 | 11 | 7 | 7 | 8 | 22 | 25 | 27 |
| | Gloved, 2.5 psi | | 6 | 8 | 7 | 7 | 4 | 4 | 2 | 2 | 4 | 10 | 9 | 14 |
| 17 | Barehanded | | 17 | 21 | 18 | 18 | 18 | 19 | 14 | 15 | 17 | 44 | 53 | 49 |
| | Gloved, no pressure | | 9 | 9 | 10 | 6 | 8 | 5 | 4 | 4 | 5 | 16 | 14 | 10 |
| | Gloved, 2.5 psi | | 4 | 5 | 4 | 2 | 2 | 2 | 1 | 1 | 1 | 6 | 4 | 5 |

* Terminology in this report follows that of the Purdue Pegboard instructions (ref 13).

TABLE 3

DEXTERITY TEST SUMMARY: MEANS OF 17 SUBJECTS

| Conditions | Right Hand | Left Hand | Both Hands | Assembly |
|---------------------|------------|-----------|------------|----------|
| Barehanded | 49.5 | 49.0 | 41.0 | 128.7 |
| Gloved, no pressure | 32.2 | 30.6 | 21.3 | 55.3 |
| Gloved, 2.5 psi | 17.5 | 16.9 | 8.7 | 25.8 |

TABLE 4

DEXTERITY TEST SUMMARY IN PERCENT (N = 17)

| Conditions | Right Hand | Left Hand | Both Hands | Assembly |
|---------------------|------------|-----------|------------|----------|
| Barehanded | 100% | 100% | 100% | 100% |
| Gloved, no pressure | 65% | 63% | 52% | 43% |
| Gloved, 2.5 psi | 35% | 35% | 21% | 20% |

the subject's body size and suit size, and between his hand size and glove size, because the resulting expansion in either case tended to force the fingertips of the glove away from the fingertips of the subject. Another factor was the stiffening of the pressure suit, and especially the glove fingers under pressure, increasing the muscular effort necessary to perform the tasks. Both factors combined to reduce the subject's dexterity.

CONCLUSIONS

1. The Purdue Pegboard Test is considered to be a fairly delicate test of the hand dexterity of a subject wearing the HAK-3/P-22S-2 pressure gloves.
2. A pressure-suited subject wearing those gloves unpressurized must expect a decrement to about 65%, or less, of his ungloved dexterity in such tasks.
3. The subject pressurized to 2.5 psi in the specified equipment must expect a further decrement to about 35%, or less, of his ungloved dexterity in such tasks.

LIST OF REFERENCES

1. Barter, J.T., and M. Alexander, A Sizing System for High Altitude Gloves, WADC Technical Report 56-599, Wright Air Development Center, Wright-Patterson Air Force Base, Ohio, December 1956.
2. Bradley, James V., Effect of Gloves on Control Operation Time, WADC Technical Report 56-532, Wright Air Development Center, Wright-Patterson Air Force Base, Ohio, November 1956.
3. Bradley, James V., Glove Characteristics Influencing Control Manipulability, WADC Technical Report 57-389, Wright Air Development Center, Wright-Patterson Air Force Base, Ohio, August 1957.
4. Emanuel, I., M. Alexander, E. Churchill, and B. Truett, A Height-Weight Sizing System for Flight Clothing, WADC Technical Report 56-365, Wright Air Development Center, Wright-Patterson Air Force Base, Ohio, April 1959.
5. Gerard, R.W. (Editor), Methods in Medical Research, Vol No. 3, Yearbook Publishers, Inc, 1950.
6. Henley, Eugene H., "Factors Related to Muscle Tension," Archives of Psychology 27: 1-44, New York, 1935.
7. Hertzberg, H.T.E., G.S. Daniels, and E. Churchill, Anthropometry of Flying Personnel - 1950, WADC Technical Report 52-321, Wright Air Development Center, Wright-Patterson Air Force Base, Ohio, September 1954.
8. Hertzberg, H.T.E., Some Contributions of Applied Physical Anthropology to Human Engineering, WADC Technical Report 60-19, Wright Air Development Center, Wright-Patterson Air Force Base, Ohio, January 1960.
9. Patterson, D.G., et al, Minnesota Mechanical Ability Tests, University of Minnesota Press, Minneapolis, Minnesota, 1930.

10. Pierce, Bernard F., "Effects of Wearing a Full-Pressure Suit on Manual Dexterity and Tool Manipulation," Human Factors 5, No. 5: 479 October 1963.
11. Remmers, H.H., and J.W. Schell, "Testing the O'Conner Wiggly Block Test," Personnel Journal XII: 155-159, 1933.
12. Tiffin, Joseph, Industrial Psychology, Prentice-Hall, 1947.
13. Tiffin, J., and E.J. Asher, "Norms and Studies of Reliability and Validity," Journal of Applied Psychology 32 No. 3: 234-247, 1948.